

Docket No. AUS920010564US1

**APPARATUS AND METHOD OF REPAIRING A PROCESSOR ARRAY FOR A
FAILURE DETECTED AT RUNTIME**

BACKGROUND OF THE INVENTION

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1. Technical Field:

The present invention is directed to an apparatus and method of repairing a processor array for a failure detected at runtime.

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2. Description of Related Art:

The IBM pSeries computing systems contain several advanced features intended to enhance the availability of systems. One such feature is persistent deallocation of system components, such as processors and memory.

Persistent deallocation provides a mechanism for marking system components as unavailable and preventing them from being configured into systems during system boot. The service processor firmware marks the components unavailable if the component failed a test at system boot, had an unrecoverable error during run time, or if the component exceeded a threshold of recoverable errors during run time suggesting that it might be more susceptible to an uncorrectable error later on.

25 Another such feature of the IBM pSeries computing
systems is called dynamic deallocation for system
components, such as processors and memory. This feature
allows a component to be removed from use during run time
should the component exceed a threshold of recoverable
30 errors.

Processors shipped in many of the pSeries systems have internal arrays such as L1 or L2 caches. An

advanced feature of these arrays is the incorporation of extra memory capacity that can be configured on a bit by bit basis to replace failed array elements. Configuring this extra memory capacity allows for hardware that can

5 repair around damaged arrays and can continue to function without replacement or degradation.

Originally these spare bits were only used when an error in an array was detected during system boot. This made the extra memory capacity feature useful for

10 repairing processor arrays during the manufacturing process. However, for systems already shipped to the end-user, the function could not be effectively utilized because, in functioning systems, array bits that go bad will tend to be detected during runtime as opposed to at

15 system boot. Because of this, the previously mentioned mechanism of persistent deallocation marks the processor component as bad without ever invoking the mechanism to determine if the array could be repaired.

Thus, it would be beneficial to have an apparatus

20 and method for invoking the mechanism to determine if an array can be repaired and to repair the array if possible, before the processor component is marked as bad by the persistent deallocation mechanism.

P D F P R O T E C T E D

SUMMARY OF THE INVENTION

The present invention provides an apparatus and method of repairing a processor array for a failure detected at runtime in a system supporting persistent component deallocation. The apparatus and method of the present invention allow redundant array bits to be used for recoverable faults detected in arrays during runtime, instead of only at system boot, while still maintaining the dynamic and persistent processor deallocation features of the computing system.

With the apparatus and method of the present invention, a failure of a cache array is detected and a determination is made as to whether a repairable failure threshold is exceeded during runtime. If this threshold is exceeded, a determination is made as to whether cache array redundancy may be applied to correct the failure, i.e. a bit error. If so, firmware makes note of the failure in persistent storage using status bits which mark what array saw the threshold exceeded.

At some time later, the system undergoes a re-initial program load (re-IPL) at which time it is determined whether an array failure is detected by a self test of arrays associated with the processor. If a failure is detected, a determination is made as to whether any status bits are set for arrays other than the cache array that experienced the present failure, if so, the processor is marked unavailable. If not, a determination is made as to whether cache redundancy can be applied to correct the failure. If so, the failure is corrected using the cache redundancy. If not, the processor is marked unavailable.

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These and other features and advantages of the present invention will be described in, or will become apparent to those of ordinary skill in the art in view of, the following detailed description of the preferred 5 embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The 5 invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

10 **Figure 1** is a pictorial representation of a data processing system in which the present invention may be implemented;

15 **Figure 2** is an expanded view of the internal components of processors of **Figure 1**;

15 **Figure 3** illustrates the operation of a known system for compensating for a detected failure using array redundancy at IPL;

20 **Figure 4** illustrates the runtime behavior of a known system and explains why the persistent deallocation feature causes the system to not be able to take advantage of array redundancy;

20 **Figure 5** illustrates the operation of a known system during running of diagnostic procedures;

25 **Figure 6** is a flowchart outlining an exemplary operation of the present invention at runtime where a single bit error exceeds a threshold;

25 **Figure 7** is a flowchart outlining runtime operating system behavior according to the present invention;

30 **Figure 8** is a flowchart of service processor firmware behavior at the next IPL following the detection of an array error during runtime in the present invention;

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Figure 9 is a flowchart outlining the operation of customer run diagnostics according to the present invention; and

- Figure 10** is a flowchart outlining an exemplary 5 operation of a servicer diagnostic procedure according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a mechanism for providing repair of processor arrays at runtime. Before 5 describing the details of the preferred embodiments of the present invention, it is important to have an understanding of the terms used herein. Therefore, the following is a brief description of the terms as they will be used in the following detailed description of the 10 preferred embodiments:

BIST - Built in Self Test

A test of a component performed with the help of self-testing circuitry within a component. Such tests are generally run before the component becomes 15 operational.

ABIST

One such self-test used to determine the function of a component such as the processor and in the case of the processors described in this document, finding solid 20 internal array faults.

POST - Power On Self Test

A test of a component or part of a system generally performed with system power to the component. Depending on design, a BIST could be part of the Power 25 on Self Test of a system.

IPL - Initial Program Load

Generally speaking, the process of taking a system from a powered-off or non-running state to the point of loading operating system specific code. This 30 process would include running through BIST and/or POST

tests of various components. In a multi-processor system all functioning processors would go through the IPL process.

IPLed - System went through Process of IPL

- 5 Generally speaking that a system or processor was brought up through the IPL process.

Service Processor

- A processor that is separate from the processors used to run an operating system in a system. The service processor runs specialized firmware code to run portions of the IPL , generally including BIST. The service processor usually has controlling access to the hardware including the ability to start and stop processors and read fault isoation registers in the various components. The service processor may also be available to help diagnosis system problems that occur during run time.

System Firmware

- 20 A layer of firmware that runs on the same processors as the operating system and is used to provide a low level of interface to various hardware components while isolating the operating system from the details of that hardware access. The system firmware may communicate with the Service Processor of the system.

25 Firmware

In this description, firmware as a general term will be used when a function is described that is performed by one of, or a combination of, system and service processor firmware.

RTAS - Run Time Abstraction Services

The interface protocol between the system firmware and the operating system. RTAS is comprised in part of a set of functions or calls that the operating system 5 can make to the system firmware.

Event-Scan

A particular RTAS call that the operating system makes periodically to the system firmware. In the return 10 from the call, the system firmware passes back any error information it has not yet sent to the operating system. These can be errors detected during the IPL process (called POST errors) or non-fatal errors detected during run time.

POST Error

15 Any error that occurs during the IPL process. Generally these are communicated by the service processor firmware to the system firmware. The system firmware in turn reports these errors through event-scan to the operating system.

20 Predictive Failure

Any non-fatal error condition that can be considered predictive of a future fatal failure. An example is a series of correctable memory errors that indicate a single bit of a memory module has failed. This is 25 considered predictive of a possible fatal error since if any random failure occurs on another bit within the same ECC word, the system would suffer an uncorrectable or fatal error.

SRC - Service Request Code

An alphanumeric identifier associated with an error
that can be used by a servicer of a system to
determine what actions to be taken to correct a
5 problem.

Diagnostics (Diags)

Generally a program for determining if a system has a
problem requiring service. For this document diags is
a program that uses the operating system to test
10 devices, do an analysis of the error log and to verify
and record repairs.

Servicer

Qualified person who diagnoses hardware problems,
replaces defective parts and verifies repairs.

15 Error Log

A history of system error events. For this document
the System error log is maintained in the operating
system and can be queried from the operating system
directly or through the use of diagnostics.
20 Diagnostics have the ability to record in the log when
a repair has been made on a device with an error so
that future diagnostics error log analysis does not
continue to report the error.

Persistent Deallocation

25 A system feature that marks a component such as a
processor as being "unavailable" for use during an
IPL. The feature (also known as Repeat Gard) will mark
the component bad if the processor fails during the
IPL, if a fatal error occurs during run time that is

isolated to the component, or if a threshold of non-fatal errors is reached (a predictive failure.)

Dynamic Deallocation

A system feature that migrates all workload of a
5 component such as a processor during run time and prevents any new workload to be added to the component while the system is still operating. This feature of the operating system (also known as CPU Gard for a processor) migrates the workload if a threshold of
10 non-fatal errors is reached (a predictive failure.) Generally this feature must be enabled by a customer if the customer desires it to be active. It is used in conjunction with Persistent Deallocation to ensure that the component is not configured back in to the
15 system on the next IPL.

Thread

A unit of workload for a processor.

AIX

A native operating system for the IBM pSeries systems.
20
With reference now to the figures, **Figure 1** illustrates a block diagram of a data processing system that may be used to implement the present invention. Data processing system **100** may be a symmetric multiprocessor (SMP) system including a plurality of processors **102** and **104** connected to system bus **106**. Alternatively, a single processor system may be employed. Also connected to system bus **106** is memory controller/cache **108**, which provides an interface to local memory **109**. I/O bus bridge
25

110 is connected to system bus **106** and provides an interface to I/O bus **112**. Memory controller/cache **108** and I/O bus bridge **110** may be integrated as depicted.

Peripheral component interconnect (PCI) bus bridge
5 **114** connected to I/O bus **112** provides an interface to PCI local bus **116**. A number of modems may be connected to PCI local bus **116**. Typical PCI bus implementations will support four PCI expansion slots or add-in connectors. Communications links to other computing devices may be
10 provided through modem **118** and network adapter **120** connected to PCI local bus **116** through add-in boards.

Additional PCI bus bridges **122** and **124** provide interfaces for additional PCI local buses **126** and **128**, from which additional modems or network adapters may be
15 supported. In this manner, data processing system **100** allows connections to multiple network computers. A memory-mapped graphics adapter **130** and hard disk **132** may also be connected to I/O bus **112** as depicted, either directly or indirectly.

20 In addition to the above, a service processor **190** is provided. The service processor **190** has access to the processors, such as processors **102** and **104**, through separate service path **195** for scanning data in and out of processor registers and controlling processor clocks. The
25 service processor actually has access to nearly every element in the system other than power and I/O adapters/devices, but for the purposes of simplicity of the present disclosure the service processor **190** is only shown as having access to the processors is sufficient.

30 The service processor **190**, in a preferred embodiment, performs the functionality of the present invention in

repairing arrays in processors, such as processors **102** and **104**. The service processor **190**, during runtime, determines if a bit in an array of a processor is bad. If a bit is determined to be bad in the array, an attempt is
5 made to repair the array. If the processor array cannot be repaired, or if the repair attempt does not fix the problem, the processor may be taken off-line and a user may be informed of a need to replace the part containing the faulty processor.

10 Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 1** may vary. For example, other peripheral devices, such as optical disk drives and the like, also may be used in addition to or in place of the hardware depicted. The depicted example is
15 not meant to imply architectural limitations with respect to the present invention.

The data processing system depicted in **Figure 1** may be, for example, an IBM pSeries system, a product of International Business Machines Corporation in Armonk,
20 New York, running the Advanced Interactive Executive (AIX) operating system or LINUX operating system. Alternatively, the data processing system may be any type of data processing system that supports the use of persistent component deallocation.

25 **Figure 2** is an expanded view of the internal components of processors **102** and **104** of **Figure 1**. As shown in **Figure 2**, the processor **102/104** includes processing elements **210**, level 1 (L1) cache **220** and a level 1 cache array **230**. An additional level 2 (L2) cache
30 **240** may be provided external to the processor **102/104**. The terms "level 1" and "level 2" cache refer to the "closeness" of the cache to the processing elements **210**.

An L1 cache is a memory cache built into the processor chip or packaged within the same module as the chip. An L2 cache is a memory cache that is external to the processor chip or module.

5 The present invention provides a mechanism by which array redundancy in the cache array, in the depicted example, L1 cache array **230**, may be used to compensate for errors detected during runtime and not only at initial program load, i.e. system boot. In this way, the
10 present invention allows a system to first attempt to compensate for an error by using array redundancy before the processor or other component is marked as unavailable due to errors.

As previously noted, known systems are capable of
15 taking advantage of array redundancy in systems if a failure is detected during initial program load. Such a failure would be, for example, a bit error detected by the processor built-in self test known as ABIST. This self test is run under the control of the service
20 processor firmware during IPL. If a bit error is detected and a spare is available, the spare bit is used in place of the faulty one as part of the process.

Figure 3 illustrates the operation of a known system for compensating for a detected failure using array redundancy at IPL. As shown in **Figure 3**, the operation starts with a determination by the service processor firmware as to whether the processor is marked unavailable due to errors (step **310**). If the processor is marked as unavailable due to errors, the service
25 processor will insure that the processor is not used and will create a POST error message for the operating system
30 (step **320**).

If the processor is not marked as unavailable due to errors, the service processor initiates a built-in self test of the processor (step **330**). As part of the process, a determination is made as to whether the array failed the built-in self test (step **340**). If not, the service processor firmware allows the initial program load of the processor and no error messages are sent (step **350**). If the array failed the BIST, a determination is made as to whether redundancy may be applied to compensate for the failure (step **360**).

If redundancy can be applied, it is applied and the initial program load is run on the processor with no error messages generated (step **370**). If redundancy cannot be applied, the service processor firmware marks the processor as unavailable and the processor is not used (step **380**). The service processor firmware creates an error message for the operating system (step **390**) and the operation ends.

As previously mentioned, the operation shown in **Figure 3** is at IPL time. Currently, the known systems cannot take advantage of redundancy if the array error is detected during normal system operation, i.e. at runtime. This is due to the persistent deallocation feature of the firmware. This persistent deallocation feature detects that the array is bad, and prevents the BIST from being run against the array to the next IPL. That is, in **Figure 3**, the result of step **310** will be "Yes" and the processor will not be used.

Figure 4 illustrates the runtime behavior of a known system and explains why the persistent deallocation feature causes the system to not be able to take advantage of array redundancy. As shown in **Figure 4**, at

runtime a recoverable error threshold is exceeded for an array which could have redundant bits available (step 410). The firmware marks the processor as unavailable for subsequent IPLs due to having had an excess of 5 recovered errors (step 420). The firmware signals to the operating system that a threshold of errors was exceeded for a processor internal array (step 430) and the operation ends. The key problem with this operation is that the persistent processor deallocation function 10 prevents the processor from being considered for use in subsequent IPLs even if the array problem could be corrected at IPL.

From a diagnostics standpoint, if the array failure were detected at runtime, the processor would always be 15 called out for replacement. **Figure 5** illustrates the operation of a known system during running of diagnostic procedures. As shown in **Figure 5**, the operation starts with the start of diagnostic procedures (step 510). A decision is made whether or not to log a POST error 20 indicating the processor is not available (step 520). If a POST error is to be logged, the diagnostics indicate that the part containing the processor should be replaced (step 530). Taking this path is indicative that the system had been IPLed since the error was discovered.

25 If a POST error is not logged, a determination is made whether to log an entry indicating that the processor had a predictive failure (step 540). If not, the diagnostics return with no problems reported (step 550). If a predictive failure log entry is to be 30 entered, the diagnostics indicate that the part containing the processor should be replaced (step 560). Taking this path is indicative that the system had not

been IPLed since the error was discovered. The diagnostics operation then ends. Thus, if a failure occurs, the diagnostics will always indicate that the part containing the processor needs to be replaced.

- 5 **Figure 6** is a flowchart outlining an exemplary operation of the present invention at runtime where a single bit error exceeds a threshold. As shown in **Figure 6**, the operation starts with a recoverable error threshold exceeded for an array which could have
10 redundant bits available (step **610**). The firmware writes threshold exceeded information into persistent memory but does not mark the processor as unavailable (step **620**).

In step **620**, a predictive failure error log entry is presented by event scan to the operating system. The
15 processor is marked by, for example, a service processor, as "predictive failure experienced" with a code indicating that the processor had an array soft error threshold exceeded problem. The code may distinguish which array had the problem. This marking may, in
20 effect, be additional information stored in the same manner as the persistent deallocation information is stored in the known systems.

The firmware then signals to the operating system that a threshold of errors was exceeded for a processor
25 internal array (step **630**) and the operation ends.

Figure 7 is a flowchart outlining runtime operating system behavior according to the present invention. As shown in **Figure 7**, the operation starts with the operating system receiving a signal from the firmware
30 that a runtime predictive failure has occurred (step **710**). This may be done using an RTAS event_scan call.

The operating system logs errors into the operating system error log (step **720**). The operating system error log analysis program indicates that the system had an error where the actions are to re-IPL the system when
5 convenient and run system diagnostics to determine if the indicated problem persists (step **730**). If dynamic processor deallocation is enabled, the operating system migrates all running threads off the processor and does not allow any new ones to be dispatched to the processor
10 (step **740**).

As can be seen from **Figure 7**, a predictive failure will result in dynamic deallocation being invoked for the processor according to a set policy. The policy may be set by the user, for example. With known systems, this
15 would be considered a permanent error and a human servicer would be dispatched to replace the failed processor.

With the present invention, however, the particular error may be repairable by the hardware without the need
20 for replacement. With the present invention, when a repairable error is identified, the following actions show the steps that would normally be performed presuming an AIX operating system. Other operating systems could provide equivalent functionality:

- 25 1) when the predictive failure occurs, an entry in the AIX error log will be made indicating that there was a failure. There are mechanisms within the operating system that can be used to either automatically, or on customer request, do analysis of the error log entry.
30 This analysis will indicate a potential problem with the processor that requires the attention of a servicer;

TOP SECRET - DEFENSE

- 2) when called to repair the system, the servicer will be directed by a maintenance package for the system to run AIX diagnostic repair verification against the processor as if a fix had been made for the processor;
- 5 3) the servicer will shutdown and re-IPL the system;
- 4) the servicer will then run AIX Problem determination diagnostics;
- 5) if the processor is called out by the
- 10 diagnostics, the servicer will replace the processor; and
- 6) if the processor is not called out by the diagnostics, then the system has repaired the error without need for a processor replacement.

The above does require that the service processor
15 continue to create a POST error log entry on each IPL where a processor is persistently deallocated due to an error.

At first IPL of the system after the predictive failure, the service processor firmware will either fix
20 the array that had previously been detected as having a predictive failure or else identify the processor with the predictive failure as being bad and in need of repair. Fixing the array presumes that there is redundancy available to be applied. It also requires
25 that the array failure was such that there is now a bit problem that was solid enough to be detected by the BIST at IPL. This scenario supposes cases where the problem was very intermittent in nature when the system was first IPLed and that over the course of time the problem grew
30 solid and has hence, been detected as a predictive failure by exceeding a threshold of recoverable errors.

PREDICTIVE FAILURE

This is consistent with how most such errors are expected to be detected in operational systems.

Figure 8 is a flowchart of service processor firmware behavior at the next IPL following the detection 5 of an array error during runtime. As shown in **Figure 8**, the operation starts with a determination whether the processor is marked unavailable (step **810**). If the processor is marked as unavailable due to errors, the processor is not used and a POST error message is sent to 10 the operating system (step **820**).

If the processor is not marked as unavailable due to errors, a built-in self test is run on the processor (step **830**). A determination is made as to whether the array failed the built-in self test (step **840**). If not, 15 a determination is made as to whether there are status bits set indicating that an array had a predictive failure during runtime (step **842**). If not, the processor may be used, an unavailable status is not set, and no error messages are sent (step **844**). If there are status 20 bits indicating that an array had a predictive failure during runtime, any array status bits for the processor are removed and bits are set indicating that the processor is unavailable (step **846**). The processor is not used and the operating system is given a POST error 25 message indicating that the processor should be replaced (step **850**).

If the array failed the BIST, a determination is made as to whether redundancy may be applied to compensate for the failure (step **860**). If redundancy 30 cannot be applied, any array status bits for that processor are removed and bits are set indicating that the processor is unavailable (step **870**). The processor

is not IPLed and the operating system is given a POST error message indicating that the processor should be replaced (step **880**).

If redundancy can be applied, a determination is
5 made as to whether status bits that are set for the processor are only those status bits associated with the array that had a predictive failure during run-time (step **890**). If so, redundancy is applied and any array status bits are removed (step **892**). The processor may then be
10 used with no error messages generated (step **894**).

If there are other status bits set for other arrays associated with the processor, any array status bits for the processor are removed and bits indicating that the processor is unavailable are set (step **896**). The
15 processor is not IPLed and the operating system is given a POST error message indicating that the processor should be replaced.

Essentially what is shown in **Figure 8** is that, when it is determined that an array has an error that exceeds
20 the threshold of recoverable errors, it is not known which particular bit is bad. However, it is known which array had a bad bit.

Thus, when the BIST is run to check for array problems, potentially, an array may be found with a
25 problem other than the one that is being looked for in the first place. In that case, it is presumed that the failure on the array being looked for in the first place, has been missed. This means that it cannot be presumed that the original failure has been fixed. Therefore the
30 part containing the processor needs to be replaced.

Figure 9 is a flowchart outlining the operation of customer run diagnostics. As shown in **Figure 9**, the

operation starts with a determination as to whether a POST error in the log indicates that the processor is not available (step **910**). If so, the customer is instructed to request service on the system to replace the part

- 5 containing the processor (step **920**). This step represents the case of having an array failure and running diagnostics after the system rebooted and the service processor determined that the processor needed to be replaced. If not, a determination is made as to whether
10 there is an entry in the log that indicates the processor had a predictive failure (step **930**).

If not, the diagnostics returns with no problem found (step **940**). If the processor did have a predictive failure, the customer is instructed to request service
15 where the servicer will re-IPL the system to determine whether a part needs to be replaced (step **950**). This step represents the case of running diagnostics after an array predictive failure but before any system reboot.

Figure 10 is a flowchart outlining an exemplary
20 operation of a servicer diagnostic procedure performed in response to step **950** in **Figure 9**. As shown in **Figure 10**, the operation starts with a determination as to whether there is a POST error in the log indicating that the processor is not available (step **1010**). If so, the
25 servicer replaces the part containing the processor and then runs repair verification to remove the failure entry from the active log (step **1020**). This represents the case of running the diagnostics after the system had been re-IPLed after an array failure and the service processor
30 on the re-IPL determining that the processor needed to be replaced.

If not, a determination is made as to whether an entry in the log indicates that the processor had a predictive failure (step **1030**). If not, the diagnostic returns with no problem found (step **1040**). If so, the
5 servicer runs repair verification procedures that eliminate the predictive failure entry as being active in the error log (step **1050**). The servicer may then re-IPL the system.

After re-IPL, the servicer will then begin the
10 process outlined in **Figure 10** again. If the array could not be repaired by the service processor after IPL, then step **1010** would be true as there would be a POST error log entry. This would lead to step **1020** and the part containing the processor being replaced.

15 If the array was repaired, then there would be no POST error log entry and step **1010** would lead to step **1030**. At this step it would be determined that there was no active predictive failure error log entry (having effectively been removed previously by step **1050**). Thus
20 step **1040** would be executed indicating that the system was now fully repaired.

The previous description for the process in **Figure 10** presumes that the system was not re-IPLed before the servicer began working on it. The same process still
25 results in the desired behavior if the customer had done a re-IPL. If a previous IPL had occurred, step **1010** concerning the existence of a POST error log entry will be answered affirmatively if, on the previous IPL, the array could not be repaired. This will lead to step **1020**
30 and replacement of the processor. If the array had been repaired, then step **1010** would be answered negatively,

leading to step **1030**. Since there will be a log entry indicating that the processor had a failure, step **1050** would be performed next. In this step, the servicer will remove the predictive failure entry.

5 The servicer at this point may use information in the system error log to realize that the system had previously been rebooted and the array repaired. The service action would then be complete. **Figure 10** does not require this, however, and shows that from step **1050**,
10 the servicer would IPL the system again and follow the same procedure outlined in **Figure 10**. This time, step **1010** would be answered no and step **1030** would be answered no, thereby ending the procedure at step **1040**.

Thus, the present invention provides an apparatus
15 and method by which a processor array may be repaired during the next IPL after an array is determined to be faulty due to an exceeded threshold of recoverable errors while maintaining the ability to persistently deconfigure the processor when repair is not possible.

20 It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in
25 the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media
30 include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog

communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded

- 5 formats that are decoded for actual use in a particular data processing system.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the 10 invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of 15 ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

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